5-1939

The Ecology of Agropyron Inerme on Protected and Heavily Grazed Range Land in Cache Valley, Utah

Wallace R. Hanson

THE ECOLOGY OF *AGROPYRON INERME* ON PROTECTED AND HEAVILY GRAZED RANGE LAND IN CACHE VALLEY, UTAH

by

Wallace R. Hanson

A thesis submitted in partial fulfillment of the requirements

for the degree of

Master of Science

in

School of Forestry

Utah State Agricultural College

1939

THE ECOLOGY OF AGROPYRON INERME ON PROTECTED AND HEAVILY GRAZED RANGE LAND IN CACHE VALLEY, UTAH

by

Wallace R. Hanson

A thesis submitted in partial fulfillment of the requirements

for the degree of

Master of Science

in

School of Forestry

Utah State Agricultural College

1939

Approved:

Major Professor

For English Department

Dean of the School

Chairman of Committee on Graduate Work

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

During the past decade much attention has been attracted to the great range lands of the West. The inherently low productivity of these arid lands coupled with abnormal drought and constantly heavy use by livestock because of lack of grazing control, have caused these lands to become greatly depleted over most of the West. That the vegetation on most range land in the intermountain states is depleted appreciably is evident to the careful observer. Undoubtedly the vegetation of much of the range has decreased in quantity, but more serious in many cases is the decrease in quality. Valuable forage species have been replaced by less valuable or even worthless ones. This situation has been recognized by students of range ecology, and, therefore, management plans have been formulated to preserve or improve the forage cover. These plans have undergone changes and are still being modified as basic facts concerning the growth habits of range plants are brought to light. Grazing plans in the past were, of necessity, based upon superficial study and general impressions; plans of the future will be based upon scientific facts supplemented by experience.

The studies herein reported were made during the summer of 1938 in southern Cache Valley, Utah. The range under observation is roughly comparable to the northern intermountain grasslands. The observed range occupies the benches and foothills above the more moist valley floor.

Physiographically Cache Valley belongs in the Basin Range Province (7). The valley is bounded by 2 spurs of the Wasatch mountains, the Bear River range on the east and the Wellsville and Clarkston mountains on the west. These are composed chiefly of Palaeozoic rocks, dolomite being most common. Lying against their bases are foothills composed of conglomerates and oolitic limestones of the Salt Lake formation.

This material has been sculptured into terraces by old Lake Bonneville and is supplemented by alluvial fans at the canyon mouths. The valley fill is unconsolidated Quaterniary material.

Ecologically this valley differs somewhat from typical ones of the Basin Range. Some marked differences in plant associations are evident in passing from Cache Valley into Salt Lake Valley. Cache Valley joins the Palouse prairie on the north and bears resemblance to it floristically. Weaver (19) points out that the vegetation of regions adjoining the Palouse prairie is not far different from that within. Extensive studies would be required to ascertain into which ecological unit Cache Valley best fits.

Whether or not the vegetation on range land in this valley has changed in quantity and composition since its use for grazing is a moot question. Students of range ecology have assumed that long-established cemeteries, railroad rights-of-way, and other similar exclosures bear a vegetation very similar to the original for that and the surrounding land. Almost invariably these areas bear a heavier vegetative cover of different composition than the surrounding grazing land. If these exclosures represent the climax vegetation, then bunch wheatgrasses, _Agropyron inerme_ (Scribn. and Smith) Rudb. and _A. spicatum_ (Pursh.) Scribn. and Smith, were once dominant on the benches and alluvial fans in Cache Valley. Sagebrush, _Artemisia tridentata Nutt._, was a subdominant to the grass but dominated the vegetation on the higher exposed slopes. The abundance of sagebrush on the heavily-grazed benchland and the sparsity of bunch wheatgrass suggest invasion of sagebrush into climax grassland.

Bunch wheatgrass was scarce or lacking in many places visited along the benches. That this grass had been dominant was frequently evidenced by the presence of an almost pure stand of wheatgrass on one side of a range division fence and almost pure sagebrush or sagebrush-weed on the other (see figure 1). On parts of the range where grazing had been more moderate, wheatgrass was still abundant; but it had undergone considerable reduction in number and size of plants.

The question naturally arises as to the causes, within the plant, which lead to the disappearance or severe reduction of the wheatgrasses under current grazing practices. Investigators have recognized the importance of food accumulations in the economy of the plant; but other than the work done by McCarty (10, 11, 12) and Aldous (1), little investigation of carbohydrate relationships of range forage species has been undertaken. This phase of the problem has to do with the permanence of the climax plants and sustained yield of forage from year to year. Closely allied are the relationships of underground parts to longevity and forage yield. Because roots are less apparent and more difficult to study, they are often neglected in the consideration of a plant.

A sustained stand depends partly upon longevity of the plants, partly upon seed production and the subsequent establishment as seedlings. Seed crop, in turn, depends upon plant vigor, which in turn depends upon a sturdy root system and a store of carbohydrates to initiate strong growth in the spring.

To lend enlightenment to the above hypotheses, information on the following was sought:

1. Growth habits of bunch wheatgrass, especially underground.
2. Effects of grazing upon root growth.
3. Effects of grazing upon seed production.
4. Effects of grazing upon carbohydrate stores in the subterranean parts.

Figure 1. Photograph showing protected and overgrazed wheatgrass range

REVIEW OF LITERATURE

It is only in recent years that attention has been turned to the management of western ranges and that a literature on the subject has been built up. The earlier investigations were more general and dealt chiefly with yield under different conditions. Then particular plants were investigated, and, as the need has demanded, more specific knowledge concerning growth habits and relationships of the important forage plants has appeared in print.

As far as the writer is aware, there exists no published study devoted to this phase of the study of Agropyron inerme nor its very near relative, Agropyron spicatum. There has been some pertinent research with other western range grasses which lends information and suggestions for an understanding of this species.

Ecological Relationships. Clements, Weaver, and Hanson (6) established the fact that the kind and condition of the root system are the primary factors determining success in ecesis and subsequent competition. Weaver (21) pointed out that most root systems of prairie grasses deteriorate under heavy grazing and are less able to cope with drought and rigors of winter.

Biswell and Weaver (4) studied the effect of frequent clippings upon the roots and tops of some prairie grasses. The size of both tops and roots was greatly reduced. Clipped plants failed to produce new rhizomes, and many old ones died. The length of roots was greatly decreased, and the relative production of roots was more greatly reduced than that of tops. The average weight of roots of clipped plants was 10.1 percent of the controls.

Flory and Trussel (8) studied the root habits of blue grama (Bouteloua gracilis), western wheatgrass (Agropyron smithii), and galleta (Hilaria jamesii) in their relation to soil conservation. The root systems of all these grasses were markedly decreased under heavy grazing.

Stored Food Relationships. Although a more or less limited number of species has been studied to determine the effect of grazing or clipping upon reserve food, the literature seems generally in agreement. The conclusion is well-established that reduction of the photosynthetic area during the growth period decreases the reserve of carbohydrate stored in the root and stem bases; and that this, in turn, reduces subsequent vigor and yield (1, 10, 17).

March of Carbohydrates. McCarty (12) studied the march of carbohydrates throughout the growth of Bromus carinatus, Elymus ambiguous, and Muhlenbergia gracilis. As the growth cycle of each varied according to inherent character and environmental factors, so also the seasonal march of carbohydrates varied somewhat. Starch and sugars were found to be the most potent stored foods. In general the starch and sugar content of roots and stem bases reached a maximum immediately following current seasonal growth, declined slightly during the rest period, and reached the minimum during the formative stages of shoot development. For incipient growth, both root and shoot, the plant depends completely upon the stored carbohydrate for energy and building material. The plant soon reaches the stage where it manufactures carbohydrate, but this carbohydrate is used by body processes as fast as it is manufactured. At the point where growth rate begins to decline, storage begins. This point is not exactly known for most plants.

Carbohydrate Foods. The carbohydrate foods are commonly grouped into 3 classes: sugars, starches, and hemicellulose (10, 13). The starch fraction contains that part of the carbohydrates hydrolysable by the enzyme maltase or ptyalin. Hemicellulose as used by Miller (10) includes a heterogeneous group of substances not soluble in water but in weak alkalies, and which on hydrolysis yield principally galactose, mannose, and pentose, and are generally considered as anhydrides of these sugars. Norman (14) showed that the true hemicelluloses are polyuronides containing 1 hydroxyl group and yielding uronic acid and hexoses and pentoses such as rhamnose, d-glucose, d-xylose, l-arabinose, etc. This arrangement of Norman's excludes the hexosans and pentosans from hemicellulose. However, in this paper these will be included as hemicellulose in the analysis.

CHOICE OF STUDY AREAS

A superficial examination was made of much of the range land in southern Cache Valley. From this range land 3 areas were selected for more intensive study, these being considered as broadly representative of soil and vegetative conditions. The areas included sedentary and alluvial soil of various textures, depths, and degrees of rockiness. Various slopes and exposures were represented. The areas supported vegetative covers varying from climax wheatgrass to severely depleted weedy stands. Although *Agropyron spicatum* is common over these ranges, on all the study areas A. inerme* was the dominant grass.

---

* *Agropyron spicatum* (Pursh) Scribn. and Smith, and *A. inerme* (Scribn. and Smith) Rydb. are differentiated by Hitchcock only by the presence or absence of awns. In some works (20) *A. inerme* is considered as a variety of *A. spicatum*, while in others it is considered as a subspecies (16). The 2 are reported as growing together in the Palouse prairie (16), and such is the case on the ranges observed in this study. So similar are the 2 in habitat and growth habits that it seems logical that observations and conclusions in this paper would apply equally well to *A. spicatum*.

UNDERGROUND GROWTH HABITS

Method of Procedure. For studies on root growth and habits a representative climax wheatgrass community was selected. The soil was an alluvial silt loam, being very suitable for root excavation. On a representative climax 3 wheatgrass root systems were excavated and charted. Seven others were examined, their maximum depths and spreads measured, and their general patterns were noted.

Methods of excavation and study were essentially the same as those used by Weaver (19). A bank was taken advantage of to save time and labor of digging. Weaver warns against this procedure, as an open-face bank gives an unnatural environment. In this case, however, the bank had been very recently cut to its present position, and all plants observed were at least a meter from the exposed surface. Although Weaver's method is inadequate for quantitative studies, as shown by the recent work of Pavlychenko in Saskatchewan (15), it is useful in revealing the general pattern, extent of growth, and general habits.

The roots were studied as dug from the walls of the excavation. As each was teased from the soil with an ice pick, it was charted. A plane surface drawing does not show the true position of the roots but gives a fair representation of pattern. Since the plants considered produced from 300 to 600 main roots, it was impossible to chart them all. An attempt was made to choose a representative sample for photographing (figure 2).

Further excavation was done to find maximum depth and spread. Spread was reported in distances from the center of the crown (table 1).

A bisect showing 3 bunches of wheatgrass and 1 Helianthella plant was sketched from the same excavation as above (figure 3).

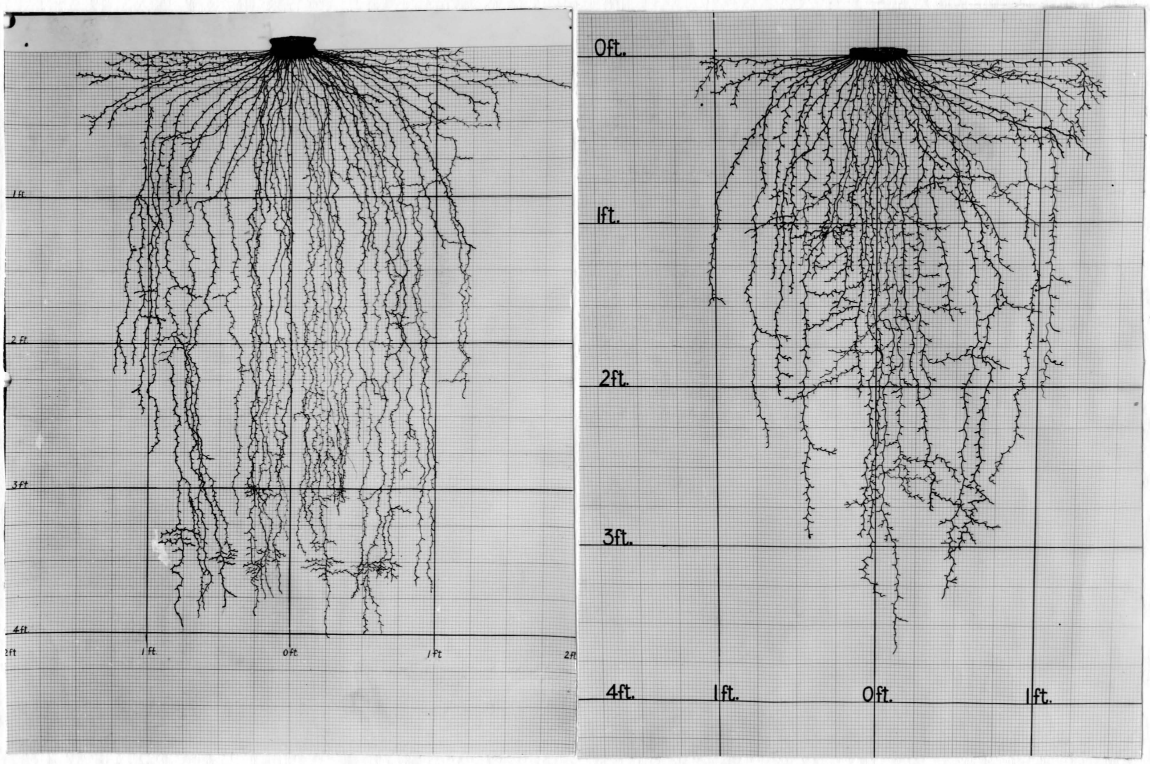

Figure 2. Charts of <u>Agropyron</u> <u>inerme</u> roots

Measurements were taken and an estimate made of the proportion of root weight to herbage weight. The herbage of 3 representative plants was dried and weighed. The seed crop had previously fallen. A bisect was cut through the center of the root system. Samples of a given volume were obtained by use of a sampler described elsewhere in this report (figure 4). Samples were taken at 6 positions. The roots were freed of soil by the use of water, air dried, weighed, and averaged. This average weight represented the weight of roots per cubic decimeter of soil. The entire volume of soil occupied by roots was estimated from measurements taken of depth, spread, and from the shape of the system as shown by the chart (figure 2). An estimate of the weight of the root system was then obtained by multiplying volume in cubic decimeters by weight per cubic decimeter.

Results. Figure 2 shows photographs taken from charts of excavated root systems. The pictures illustrate the rooting habit. The upper layers of soil were especially well-occupied by roots. The finer rootlets and root hairs not shown in the chart completely permeated the soil. Extending from the crown were numerous horizontal roots. At the time of study, the upper few inches of soil and roots were quite dry, and these roots were likely not actively absorbing.

Contrasting with these horizontal roots, the main body of roots grew downward and fed in deeper soil horizons. The roots were, in the main, positively geotropic. Some that began horizontally suddenly turned downward. Branches were less responsive to geotropism, many finer subsidiary branches being horizontal. Actively absorbing rootlets were more numerous in the horizon containing more moisture. In an old, soil-filled rodent burrow where the soil was loose, well-aerated, and also fairly moist, absorbing rootlets were numerous and bore a profusion of root hairs. The main roots and primary branches were not evenly distributed through the soil of the B horizon but followed lines of least resistance, such as rotted woody roots, insect burrows, and checks in the soil. Root hairs were not confined to regions near the tips but extended for several inches along many rootlets. The shallower horizontal roots absorb moisture in times of light rains only, while the deeper roots draw moisture from the more permanent supply in the lower layers.

Table 1 shows average maximum root spread and depth for the area bearing a climax wheatgrass stand. Maximum depth of all plants examined was fairly constant, ranging from 3.5 to 4 feet. However, across a coulee and about two hundred yards away, in a deep sandy soil with good moisture, roots penetrated to a depth of 6 feet.

Table 1. Average dimensions of root system of _Agropyron inerme_ and ratio of root weight to herbage weight

Maximum depth	Maximum spread	Cross section of feeding area	Ratio of root wt. to herbage wt.
3'10"	1'6"	4.2 sq. ft.	13.1

Lateral spread was less constant than depth, varying with available space. In the climax stand the root system of each plant contacted and, to a limited degree, intermingled with that of its neighbors. Deep-rooted perennials represented by _Helianthella uniflora_, feed partly in the soil used by the wheatgrass, but also send roots into deeper strata (figure 3).

Most of the plant weight was actually underground. An average of estimations shows the underground parts to weigh about thirteen times as

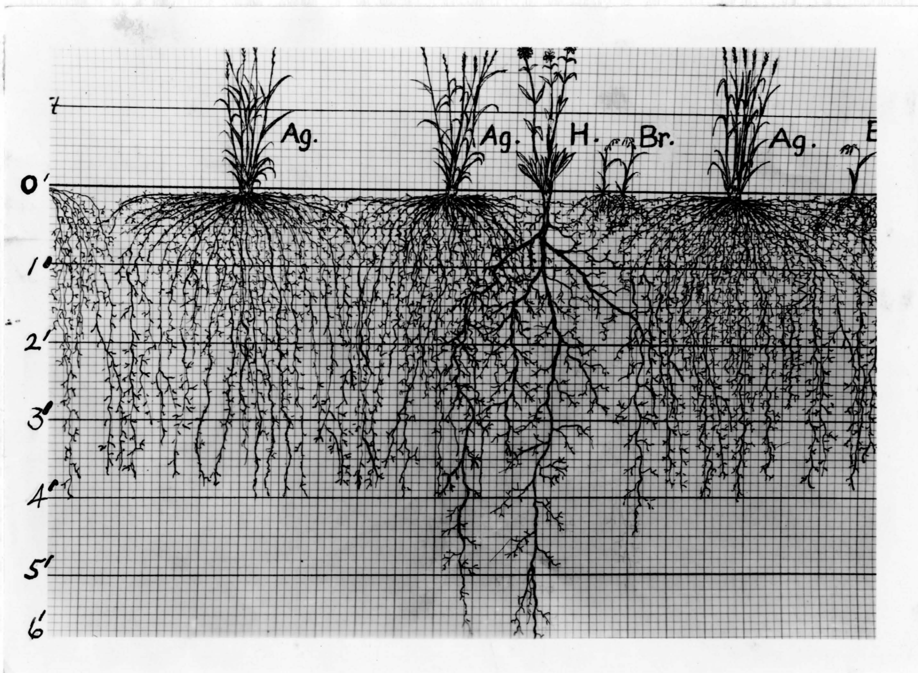

Figure 3. Bisect through climax stand of Agropyron inerme

Legend: Br.--*Bromus tectorum*
Ag.--*Agropyron inerme*
H.--*Helianthella uniflora*

much as the herbage (table 1). This estimation did not include root hairs and finer rootlets which passed through the screen during washing. Hence, root weight might have been appreciably greater had all root parts been included.

Figure 3 illustrates that under undisturbed conditions the soil mass is well-occupied by *Agropyron* roots from very near the surface to a depth of about four feet. *Bromus tectorum* growing in the intervening spaces utilizes a very shallow layer, being forced to make its growth when surface moisture is plentiful.

INTENSITY OF ROOT DEVELOPMENT

Method of Procedure. To compare root development under heavy grazing to that under light grazing a strip along a division fence between pasture and farm land was chosen. The pasture was overgrazed and the plant cover was seriously depleted. *Agropyron inerme* was replaced as the dominant by *Bromus tectorum*, and weeds also were prevalent. Across the fences within the partly cultivated field, livestock grazed in the autumn only, and the plant cover was a climax grass community. The soil was a clay loam, varying in rockiness.

To determine the intensity of root development, a sampling tool was devised (figure 4). It consists of a steel cylinder with a cutting edge and is fitted with a plunger. The handle of the plunger is marked to correspond to a given volume in the cylinder below the plunger.

A trench was dug alongside representative bunches of grass. The herbage was cut off. The sampler was placed over the center of the bunch of roots and forced vertically into the soil until the mark on the handle appeared, which designated the desired volume enclosed within the cylinder.

Figure 4. Tool for sampling root weight per unit volume of soil

The soil was then cut away from around the cylinder and the enclosed soil and root mass severed from that below by a sharp knife. The plunger was used to remove the soil block to a paper bag. After digging to a new depth, another sample could be taken. Samples were taken at 4 levels: immediately below the crown, 15 cm., 30 cm., and 45 cm. below the crown.

Random selection of plants could not be made, as the number of plants on the grazed side of the fence which were suitable for study was limited. Plants were, therefore, chosen arbitrarily. Plants had to be chosen in soil free enough from rocks that sampling was possible, and plants of a reasonable size were required.

The soil blocks were taken into the laboratory where the soil was removed by water. Each block was placed in a fine-screen strainer and washed under the tap. When the soil was removed, the live grass roots were separated from the dead ones, other roots, and foreign material. The grass roots were oven-dried at 100° C. and accurately weighed. These weights were taken as an index of root development at a given depth.

Results. The average index figure for grazed plants was 4.22 grams per cubic decimeter, as compared to 25.85 grams per cubic decimeter for protected plants (table 2). Therefore, the root development in the soil below protected plants was more than six times as great as below heavily grazed plants.

Many root systems of heavily grazed plants failed to extend beyond a depth of 45 centimeters, while all protected plants had good root volume at and below this depth.

The relative reduction in root weight from the upper layer to the 45 centimeter depth is greater for grazed plants than protected. The ratio of average weight at a depth of 0 centimeters to the average weight

Table 2. Weights of Agropyron inerme roots from grazed and protected areas in grams per cu. dm. of soil at various depths below the crown

Plants from heavily grazed area

Sample no.	Depth below the crown				
	0 cm.	15 cm.	30 cm.	45 cm.	Total
1	4.18 gm.	.14 gm.	.07 gm.	.07 gm.	4.48 gm.
2	4.11	.19	.09	.02	4.41
3	5.04	.07	.06	.04	5.21
4	4.86	.07	.05	.02	5.00
5	2.99	.07	.01	* .11	3.18
6	2.76	.14	.02	.00	2.92
7	3.36	.16	.05	.00	3.57
8	4.81	.09	.02	.04	4.96
Average	4.01	.12	.05	.04	4.22

Plants from protected area

Sample no.	Depth below the crown				
	0 cm.	15 cm.	30 cm.	45 cm.	Total
1	14.11	1.45	.40	.16	16.12
2	43.96	.98	.47	.19	45.60
3	14.16	1.33	.47	.26	16.22
4	49.76	1.73	.26	.19	51.94
5	23.36	.47	.35	.16	24.34
6	9.58	1.19	.30	.09	11.16
7	18.92	1.54	.91	.26	21.63
8	17.12	1.80	.70	.18	19.80
Average	23.87	1.31	.48	.19	25.85

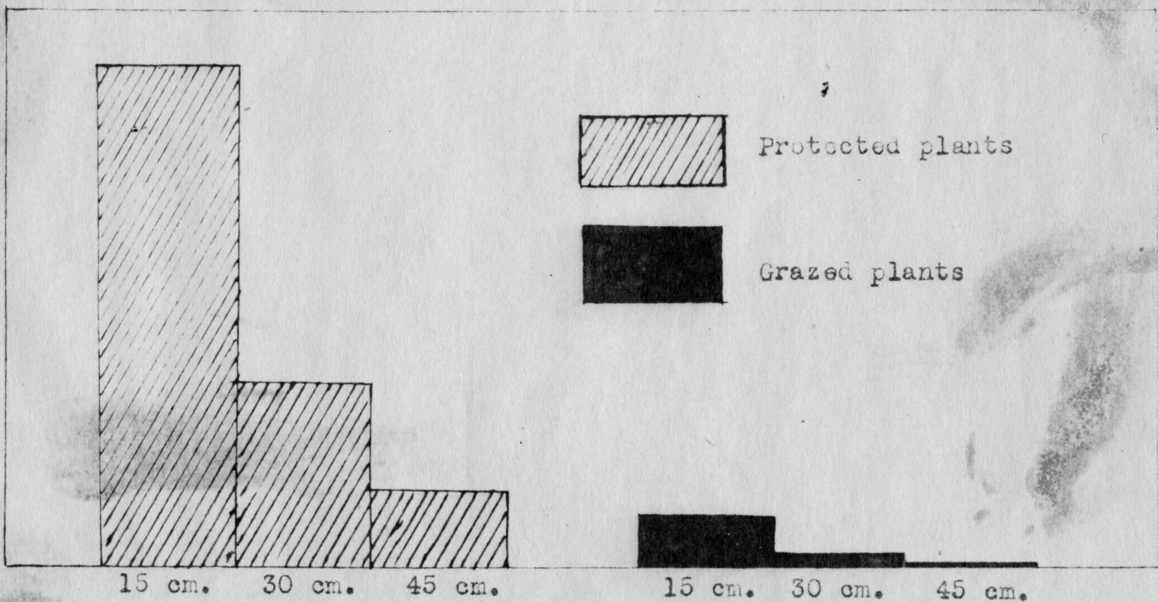

Figure 5. Relative weight of roots per cu. dm. of soil at various depths for protected and grazed plants

at a depth of 45 centimeters for grazed plants was as 4.01 : .02* or 200.5. For protected plants the ratio was as 23.87 : .19 or 125.6.

Because of the high variance within the samples it was decided to test the significance of differences. The differences between the means for protected plants and grazed plants is highly significant. Separate determinations were made for the total weight and for the weights below 15 cm.

Mean weights of total of samples at all 4 depths:
On protected area = 25.85 grams per cu. dm.
On grazed area = 4.22 grams per cu. dm.
Difference = 21.63 grams per cu. dm.
Calculated t value = 4.950
t value necessary for significance = 2.145
t value necessary for high significance = 2.977
This difference, therefore, is highly significant.

Mean weights of total of samples at lower 3 depths:
On protected area = 1.98 grams per cu. dm.
On grazed area = .20 grams per cu. dm.
Difference = 1.78 grams per cu. dm.
Calculated t value = 3.069
t value necessary for significance is the same as above.
Therefore, this difference is highly significant.

EXTENT OF ROOT SYSTEMS

Method of Procedure. On the area previously chosen for herbage study, measurements of extent were made. Six plants were selected to represent the grazed area, and 6 were selected to represent the protected area. A small trench was dug next to each plant, and the main roots and branches were followed to their tips.

Results. Data on extent of root systems are to be found in table 3.

Maximum depth of the grass roots in this location was somewhat limited by a shallow soil; nevertheless, the root systems of grazed plants were unable to utilize the full depth of soil.

---

* The root weight at the 45 cm. depth for sample number 5 appears to be erroneous and was disregarded in calculations.

Table 3. Average maximum lateral spread and depth of roots of *Agropyron inerme*

No.	Protected		Grazed	
	Depth	Lateral spread	Depth	Lateral spread
1	28	16	18	16
2	24	15	17	27
3	26	18	16	13
4	24	14	18	18
5	27	17	18	19
6	25	17	17	15
Ave.	26 in.	16 in.	17 in.	18 in.

QUANTITATIVE HERBAGE STUDY

Method of Procedure. A strip along a fence dividing grazing land from a protected field was chosen for herbage study. The grass stand on the grazed land was much sparser than on the protected land, but there was still a fair cover. The soil was rocky and relatively poor. The land sloped steeply toward the south.

To facilitate sampling and analyses of the data a system of quadrats was laid out. Along the fence dividing the grazed and protected area a strip 20 meters wide and about two hundred meters long was delimited and subdivided into transects 2 meters wide, lying at right angles to the fence. Four of these were chosen for study. Each was divided into 4-square-meter quadrats. Within each transect 2 quadrats were chosen on the protected area and 2 on the grazed area. All choices were made at random.

The basal area of *Agropyron inerme* was measured by the use of a pantograph (8). Average height and number of stalks per square meter were determined.

Figures 6 and 7 are representative pantograph charts from opposite side of the fence.

Results. The data from the measurements are summarized in table 4.

Table 4. Basal area, height, and average number of stalks of *Agropyron inerme* under grazing and protection

	Ave. basal area per sq. m. of ground	Extremes	Average height	Average no. of stalks per sq. m.
Grazed	56.8 sq. cm.	0-275 sq.cm.	51 cm.	11.4
Protected	538.5 sq. cm.	0-1767 sq.cm.	66.5 cm.	123.2

Plot 6T3 Date-July 16, 1938

Total area--1 sq. meter
Basal area--532.9 sq. cm.
Seed stalks--131

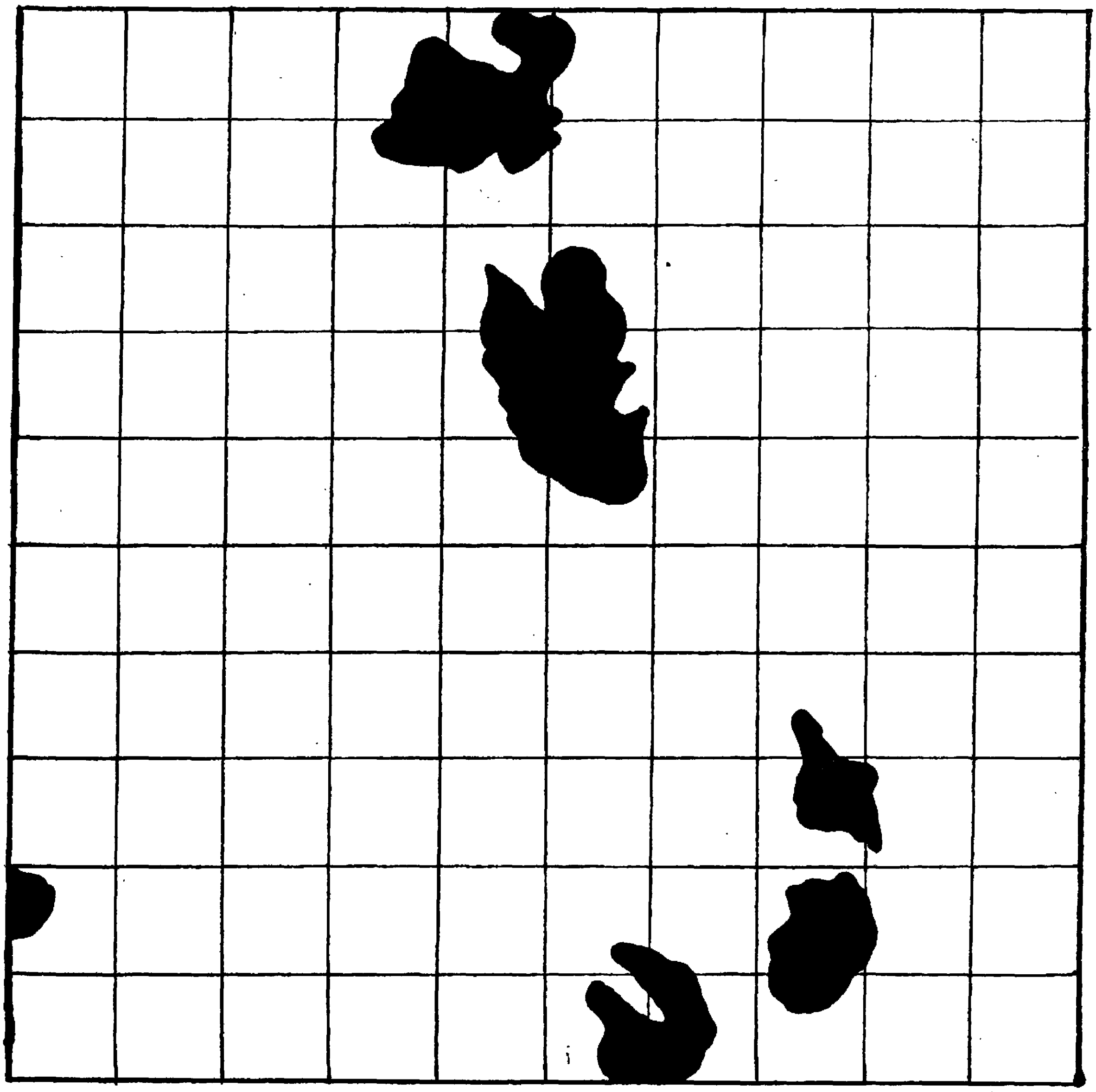

Figure 6. A representative pantograph chart of bunches of *Agropyron inerme* on a protected area

Plot 4T2 Date-July 16, 1938

Total area--1 sq. meter
Basal area--64.26 sq. cm.
Seed stalks--12

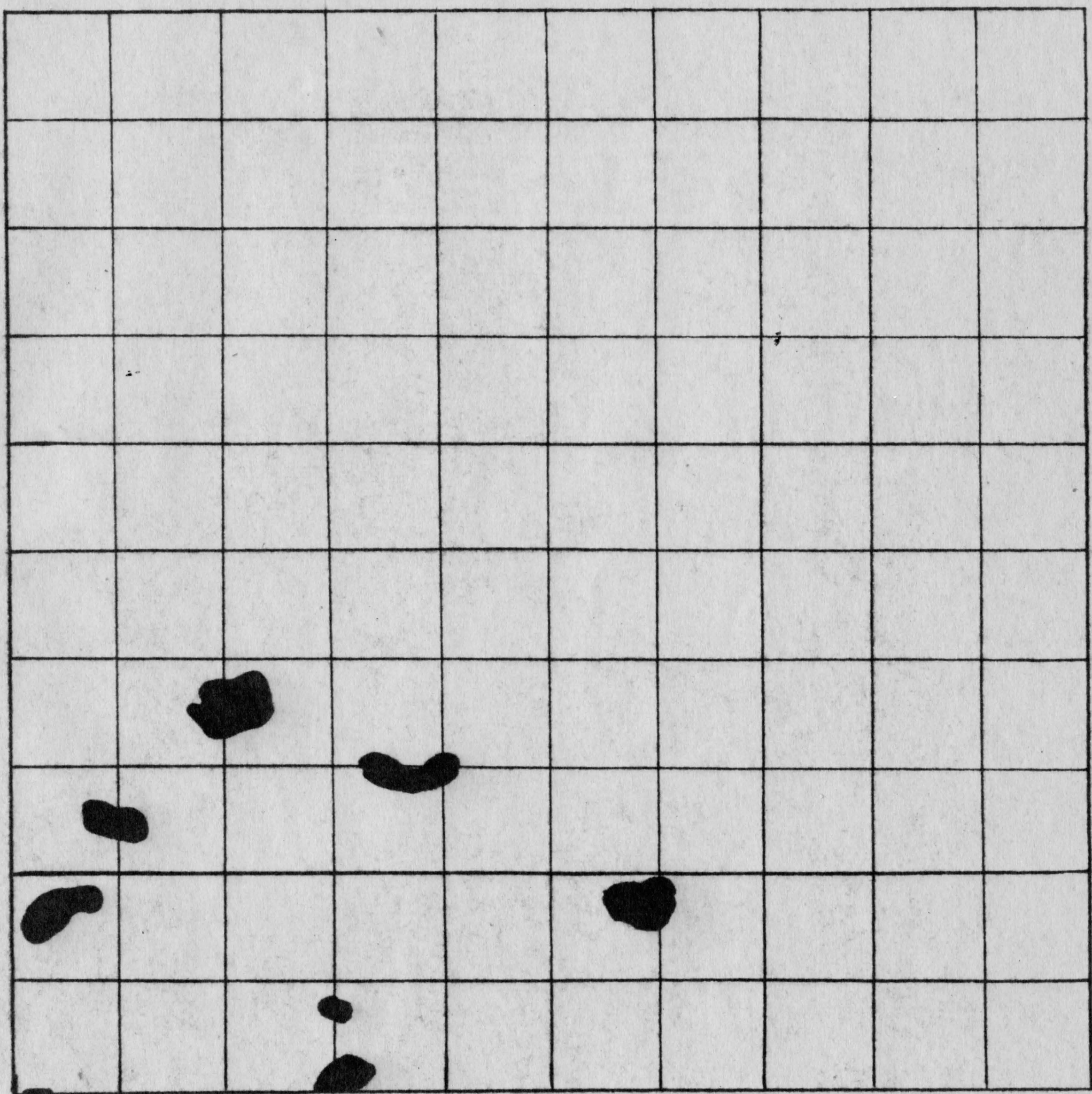

Figure 7. A representative pantograph chart of bunches of Agropyron inerme on grazed area

There is a very marked reduction in the above-ground parts of wheatgrass accompanying heavy grazing, as shown by a decrease in basal area, height, and number of seed stalks.

SEED GERMINATION

Method of Procedure. Seed samples for germination were collected from 2 locations. On the first of these, 8 samples of 10 heads each were collected in the near proximity of each of the plants studied for root intensity. On the area laid out in quadrats the heads were collected from the sample quadrats.

The mature seeds were separated from the empty florets, and germination tests included only the filled seeds.

Duplicate germination tests were conducted in which moistened blotting paper in petri dishes was used as a planting medium. The number germinated was counted after 5 days and each second day thereafter until the 15th day, after which no germination took place. Conditions adhered to were those given in Rules and Recommendations for Testing Seeds (3).

Results. Table 5 gives the results of germination tests from the first location.

Though somewhat higher germination was obtained from the seeds from grazed plants, the difference is not significant.

Mean percent germination on grazed area	=	79.7
Mean percent germination on protected area	=	73.2
Difference	=	6.5

The second set of samples was obtained from the areas laid out in quadrats for herbage study. All heads from each of 16 sample quadrats were collected.

Percent germination was determined as with the previous samples. The results appear in table 6.

Table 5. Percent seed germination of Agropyron inerme from protected and grazed plants based upon filled florets only

Sample no.	Protected: % germination at 5 days	Protected: Final germination %	Grazed: % germination at 5 days	Grazed: Final germination %
1	54.3	82.3	75.0	88.2
2	58.3	82.0	47.5	85.0
3	40.0	75.0	34.6	53.8
4	31.4	48.6	46.9	71.9
5	60.7	85.6	67.5	85.0
6	16.2	58.8	47.5	85.0
7	73.0	83.6	62.0	84.0
8	25.0	70.0	63.8	85.0
Average	44.9	73.2	55.6	79.7

Table 6. Seed heads, filled florets, percent germination, and viable seeds produced on grazed and protected stands of Agropyron inerme

Treatment	Plot no.	Heads per sq. meter	Filled florets per sq.m.	Filled florets %	% germination 5 days	% germination 15 days	Viable seeds per sq. m.
Grazed	1	14.7	33.0	24.0	33.3	83.4	27.5
	2	1.5	4.5	25.0	41.0	82.5	3.7
	3	1.5	2.8	13.8	10.0	45.0	1.3
	4	12.8	25.5	27.0	20.0	45.0	11.5
	5	6.0	27.9	30.2	31.9	86.1	24.0
	6	5.5	24.8	31.5	20.9	67.4	16.7
	7	8.0	21.2	15.6	0.0	52.0	11.0
	8	5.8	17.2	24.4	13.3	36.7	6.3
	Ave.	7.1	19.6	23.9	21.3	62.2	12.2
Protected	1	90.2	483.7	25.4	23.5	60.0	290.2
	2	156.8	1053.4	39.8	38.0	81.5	858.5
	3	123.5	968.1	42.6	18.0	74.5	721.2
	4	63.2	582.5	46.7	33.0	76.0	442.7
	5	174.2	1094.3	27.8	18.0	45.5	542.2
	6	92.0	817.0	45.0	21.0	75.5	616.8
	7	160.5	2099.3	47.2	8.0	46.5	976.2
	8	102.5	682.6	36.2	10.5	58.5	399.3
	Ave.	120.4	972.6	38.8	21.3	64.8	630.2

There is, as in the previous germination test, no significant difference between germination of seeds from the grazed area and the protected, either at 5 days or at 15 days, though germination was slightly higher for seeds from the protected plants.

Mean percent germination on grazed area at 15 days	=	62.2
Mean percent germination on protected area at 15 days	=	64.8
Difference	=	2.6

Calculated t value = 0.300
t value necessary for significance = 2.12

However, table 6 presents some important differences. The potentiality for reproduction by seed is many times greater for protected plants. The proportion of the florets that matured on protected plants exceeded that on the grazed area by 14.9 percent. Also the viable seeds per square meter of ground were almost fifty times as numerous on the protected area.

FOOD RESERVES IN ROOTS AND STEM BASES

Methods of Procedure. Sampling. The area laid out for herbage studies was used to obtain material for carbohydrate determinations. Four plants were selected from each of the transects, 2 being taken from each side of the fence. Those from the one side were protected plants, while those from the other were plants from a pasture grazed at an intensity of 7 acres per animal for 5 months. During 1938 forage was more plentiful than usual, and the grass plants considered were not grazed until after seed maturity. It is assumed, therefore, that any effect found upon storage of carbohydrate is chiefly attributable to previous years' grazing.

Each plant was dug, freed of soil by means of a stiff brush, and the roots and stem bases clipped into small pieces. This material was placed in hot 95 percent alcohol for preservation until analyses were done.

Analyses. The official methods (2) were used in the preparation and analysis of samples with the following exceptions: the reducing sugar was determined by the Shaffer and Hartman method (17). Starch was hydrolysed by the use of saliva as given by McCarty (10).

Results. The carbohydrate fractions were computed in percent of moisture-free weight of the sample.

Table 7 shows percent ash, sugar, starch, and hemicellulose in the samples taken.

Figure 8 shows graphically the relative ash, total carbohydrate, and sugar content.

The ash content of the 2 treatments is not significantly different. The t value calculated is 1.26 and the t value necessary for significance is 2.571.

The combined sugar and starch fractions are significantly higher for the protected plants. Table 8 gives analyses of the variance.

Table 8. Analyses of variance for sugar-starch fraction

Source of sums of squares	Degrees of freedom	Sums of squares	Variance	f	.05	.01
Between treatments	1	34.70	34.70	7.430	4.96	10.04
Within treatment	10	46.70	4.670			
Laboratory error	12	1.54	.128	.027	2.91	4.71
Total	23					

Variance due to treatments (grazing and protection) is significantly greater than error, and therefore the mean of the protected area is significantly greater than the grazed. The sugar and starch content

Table 7. Ash and carbohydrate content of roots and stem bases of *Agropyron inerme* from grazed and protected ranges

Treatment	Sample no.	% ash content	% carbohydrate				
			Sugars	Starch	Sugar & starch	Hemicel-lulose	Total
Grazed	1 a	9.00	1.10	2.32	3.42	8.76	12.18
	b		1.18	1.99	3.17	8.84	12.01
	2 a	10.15	1.82	2.48	4.30	9.03	13.33
	b		1.42	2.38	3.80	8.79	12.59
	3 a	18.19	1.50	3.23	4.73	8.14	12.87
	b		1.90	3.40	5.30	8.36	13.66
	4 a	8.69	1.26	3.23	4.49	7.11	11.60
	b		1.34	3.64	4.98	7.26	12.24
	5 a	12.75	2.74	3.90	6.64	15.46	22.11
	b		2.21	3.72	5.92	15.00	20.92
	6 a	12.14	2.89	1.96	4.85	9.64	14.49
	b		2.67	2.39	4.06	9.96	14.02
Average		11.82	1.84	2.89	4.64	9.70	14.33
Protected	1 a	7.88	2.30	4.11	6.41	16.01	22.42
	b		2.03	3.94	5.97	14.40	20.37
	2 a	11.59	2.03	4.07	6.10	12.63	18.73
	b		1.91	3.82	5.73	12.05	17.78
	3 a	13.04	8.24	2.89	11.13	8.36	19.49
	b		7.75	2.89	10.64	8.54	19.18
	4 a	7.88	2.50	3.60	6.10	9.47	15.57
	b		2.74	3.54	6.28	10.00	16.28
	5 a	8.05	2.70	3.94	6.64	9.02	15.66
	b		2.55	3.77	6.32	9.12	15.44
	6 a	9.71	2.30	4.60	6.90	9.63	16.53
	b		2.33	3.97	6.30	9.45	15.75
Average		9.69	3.28	3.76	7.04	10.72	17.77

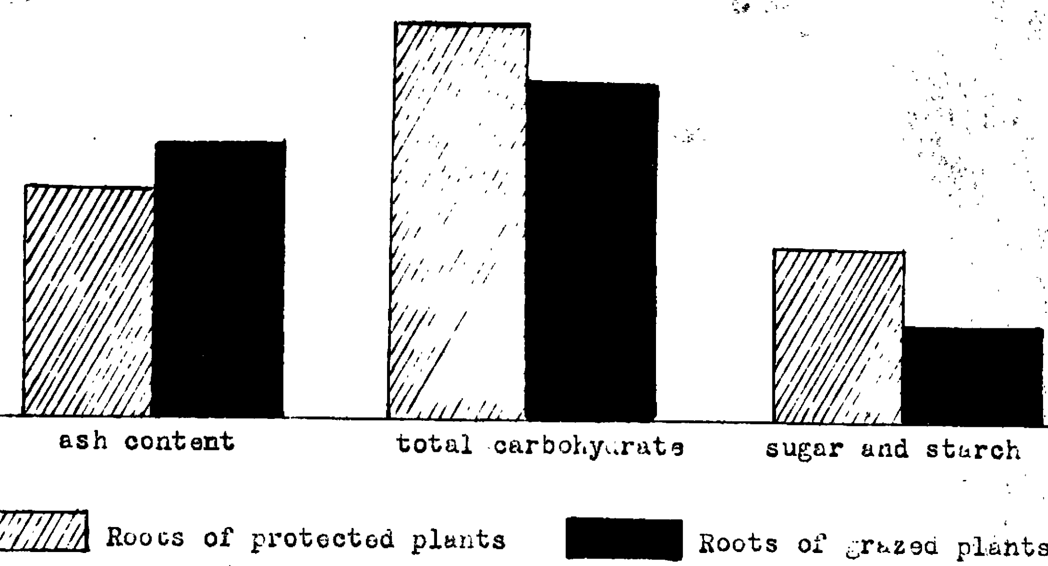

Figure 8. Relative percent ash, total carbohydrate, and starch and sugar in roots of protected and grazed plants

of protected plants, then, is significantly higher than that of heavily grazed plants.

By the same procedure the means of the total carbohydrates, including hemicellulose, are not significantly different. The f value for between treatments is 3.829, while an f of 4.96 is required for significance. The factor causing a smaller difference here is the presence of the hemicellulose. The hemicellulose fraction then does not differ significantly between protected and grazed plants.

DISCUSSION AND CONCLUSIONS

Agropyron inerme is especially well-adapted to grow in the semi-arid range lands of the northern intermountain regions of the United States. Moisture is the prime limiting factor in plant growth in this region, and the water balance of the plant determines largely its ability to exist. Water balance is a function of transpiration and absorption (9). Plants can exert very little control over transpiration (9), but the morphology of the plant may be such that it can replenish a high transpiration loss. The extensive root system of *Agropyron inerme*, which practically fills the soil to a depth of 4 to 6 feet, normally supplies water at a rapid enough rate to sustain the water balance of the plant. The shallow roots take advantage of light rains, and the deeper roots reach the subsoil moisture reserves. This efficient root system, along with an ability to grow rapidly when moisture is available and the power to produce seed abundantly, enables *Agropyron inerme* to maintain itself in a semi-arid habitat if undisturbed.

Yet, under intense grazing it yields its dominant position which it so ably holds if undisturbed. This study shows that changes brought about by overgrazing seriously alter the power of the plant to thrive in an arid environment.

Besides mechanical injury, the immediate deleterious effect of heavy grazing is the reduction of the photosynthetic area. Photosynthate is required to repair and build tissue in both roots and herbage and as food for energy release. A store is required to carry the plant through its more or less dormant period and then to supply food for root growth and incipient herbage growth. Herbage removal leads to shortage of stored food and, hence, to poor root reproduction and weakened growth in spring.

Furthermore, one year was insufficient for the plants to regain their normal food supply. In this study, plants which were ungrazed during the season that samples were taken, but which had been heavily grazed in previous seasons, showed a food reserve reduction of 19.4 percent below protected plants. The explanation seems to be one of food relationships. When re-growth began, the food supply was drawn upon to replace dead roots and to initiate herbage growth. Due to a shortage of food in previously grazed plants, normal vigor was not attained, and, even though the plants were undisturbed for one season, food manufacture was inadequate to sustain a normal root system and replenish the supply as well.

The marked reduction in depth, spread, and intensity of ramification of the roots of heavily grazed plants, as compared to roots of protected ones, was the natural result of herbage removal during growth. Stored carbohydrates are the base materials for the manufacture of proteins and the complex carbohydrates used in cell structure. A dearth of carbohydrate, therefore, would result in reduction of the root system.

The effect of a reduction of the root system upon the water relations is evident in the light of what has been said regarding water balance. Plants with depleted root systems are more susceptible to drought injury.

The longevity, even of perennial grasses, is limited, and most grasses must, therefore, depend upon reproduction by seed to maintain a stand. Agropyron inerme normally produces numerous seeds. On an area studied an average of 630 viable seeds per square meter of ground were produced. The effects of heavy grazing brought about a reduction to 12 in the number of viable seeds produced, and therefore materially lessened the chance for reproduction.

The cause of reduction in size and numbers of Agropyron inerme plants on heavily grazed ranges lies largely in these factors: removal of the photosynthetic tissue resulted in a dearth of stored food in roots and stem bases. This caused a depletion of the root system and lack of vigor in the next year's plant. A reduced root system and lack of vigor in the early season left the plant more susceptible to drought injury. Fewer viable seeds decreased the possibility of reproduction. These results act cumulatively, and depletion of the stand is progressive.

All range land observed that had been grazed during the growing season bore depleted wheatgrass stands. This indicates an overgrazed condition on most of the foothill range in Cache Valley.

SUMMARY

(1) Agropyron inerme was studied on range land in Cache Valley, Utah. Root studies were conducted in a climax association. Studies were made on protected and heavily grazed areas to compare root development; herbage and seed production; and content of sugar, starch, and hemicellulose in roots and stem bases.

(2) The habits of growth of the roots of _Agropyron inerme_ are well adapted to its habitat and insure the species a place as dominant in the area studied. The soil mass was thoroughly permeated from a depth of 2 or 3 inches to 4 or 6 feet. Root weight was 13.1 times top weight. Ground surface between the bunches was bare or sparsely occupied by very shallow-rooting annuals or deep-rooting perennials.

(3) The average weight of roots per cu. dm. of soil was 25.85 grams on protected range and 4.22 grams on heavily grazed range--a reduction to about one-sixth the normal. Maximum depth of roots of grazed plants was reduced.

(4) Germination tests of filled florets taken from protected and heavily grazed range showed no significant difference. On protected range 38.8 percent of the florets matured, and on heavily grazed range 23.9 percent matured. There were 630.2 viable seeds per square meter of ground produced on protected range and 12.2 on the heavily grazed area.

(5) Stem bases and roots of plants protected from grazing in previous years contained 17.77 percent sugar and starch, while those of plants grazed previous years contained 14.33 percent. The hemicellulose content was not significantly different.

(6) This study leads one to conclude that _Agropyron inerme_ and _A. spicatum_ could have been dominant on much range land in Cache Valley where they are at present scarce or wanting, and general observations indicate that they were dominants. Sustained yield of _A. inerme_ depends upon extent, intensity of ramification, and carbohydrate content of the root system. This study emphasizes the importance of controlled grazing.

BIBLIOGRAPHY

(1) Aldous, A. E. Relation of food reserve to growth of some pasture plants. Jour. Amer. Soc. Agron. 22:385-392. 1930.

(2) Association of Agricultural Chemists. Official and tentative methods of analysis. Washington, D. C. 1937.

(3) Association of Official Seed Analysts of North America. Rules and regulations for testing seeds. U. S. Dept. of Agr. circ. no. 840. 1938.

(4) Biswell, H. H. and Weaver, J. E. Effect of frequent clipping on the development of roots and tops of grasses in prairie sod. Ecology (4): 368-389. 1933.

(5) Calkins, H. G. Observations of plant competition, plant succession, plant soil relationships, overgrazing and erosion on sagebrush areas. U. S. Dept. of Agr. Soil Cons. Service. Region 8. Bul. 24. Soil series 3. 1938.

(6) Clements, F. E., Weaver, J. E. and Hanson, H. C. Plant competition, Carnegie Inst. Washington. Pub. 398. 1929.

(7) Fenneman, N. M. Physiography of western United States. New York, McGraw-Hill Book Co. 1931.

(8) Hill, R. R. Charting quadrats with a pantograph. Ecology 1:270-273. 1920.

(9) Maximov, N. A. The plant in relation to water. London, George Allen and Unwin Ltd. pp. 28-31, 195-215. 1935.

(10) McCarty, E. C. Grazing intensities and food relationships in Agropyron smithii. Unpublished thesis. Univ. of California. 1927.

(11) __________. The relation of growth to varying carbohydrate content in mountain brome. U. S. Dept. of Agr. Tech. Bul. 598. 1937.

(12) __________. Seasonal march of carbohydrates in Elymus ambiguous and Muhlenbergia gracilis and their reaction under moderate grazing. Plant Phys. 10:727-738. 1935.

(13) Miller, E. C. Plant physiology. New York, McGraw-Hill Book Co. 1931.

(14) Norman, A. C. Biochemistry of cellulose, poly uronides and lignin. Oxford, Clarendon Press. 1937.

(15) Pavlychenko, T. K. Quantitative studies of the entire root systems of weeds. Ecology 18:63-69. 1937.

(16) Piper, C. V. and Beattie, R. K. Flora of southeastern Washington and adjacent Idaho. Lancaster, Pa., New Era Printing Co. 1914.

(17) Sampson, A. W. and McCarty, E. C. The carbohydrate metabolism of Stipa pulchra. Helgardia 5:61-100. 1930.

(18) Shaffer, P. A. and Hartman, A. F. The iodometric determination of copper and its use in sugar analysis. Jour. Biological Chem. 45:364-390. 1920.

(19) Weaver, J. E. Root development of field crops. New York, McGraw-Hill Book Co. 1926.

(20) ______________. A study of the vegetation of southeastern Washington and adjacent Idaho. Univ. Studies XVII, No. 1. Univ. of Nebraska. Jan. 1917.

(21) ______________. Underground plant development in relation to grazing. Ecology 11 (3). 1930.